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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

HEAVY DUTY
GEARS

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

Allen F. Brewer: 32 X 12 = 384

THIS is the 384th—and last—issue of "Lubrication" under the editorship of Allen F. Brewer. He retires this month after thirty-five years with The Texas Company. Thirty-two of those years have been devoted to this magazine.

It was on a July day in 1922 that Allen Brewer first sharpened a blue pencil and took over "Lubrication's" editorial chair. During the years that Allen Brewer has been its editor-in-chief, "Lubrication" has steadily broadened the scope of its contents; format has been enlivened with illustrations and color; writing has become sprightlier. "Lubrication" has long been recognized as the outstanding technical publication in the petroleum industry. More than 50,000 copies are printed each month.

Allen F. Brewer was born at East Swanzey, New Hampshire, on June 14, 1889, and prepped for the Massachusetts Institute of Technology at Carteret Academy, Orange, New Jersey. In 1914, after graduation from M.I.T. in Mining and Metallurgy, he joined the New Jersey State Board of Public Utility Commissioners, and in 1917 went with the American International Shipbuilding Corporation.

After serving in the U. S. Navy as a commissioned officer on active duty in European waters during World War I, Mr. Brewer joined The Texas Company in 1919 as Fuel Oil Engineer with the Export Department in New York. A year later he was transferred to the Refining Department at Port Arthur, Texas, where he became Plant Lubrication Engineer. In July, 1922, he came back to New York as a member of the Sales Department and took over the editorship of "Lubrication." His official company title for 26 years has been: Technologist (Engineering) with the Technical and Research Division of the Refining Department.

Mr. Brewer is a member of the American Society of Refrigeration Engineers, the Association of Iron and Steel Engineers, the American Society of Mechanical Engineers, and has just been elected an Honorary Life Member of the American Society of Lubrication Engineers and consulting editor for "Lubrication Engineering." He is a licensed engineer in the states of New York, New Jersey and Pennsylvania. For many years he held a marine engineer's license. His by-line has appeared on many articles and papers on various aspects of lubrication which have been presented before engineering societies and widely printed in technical and trade publications.

Mr. Brewer expects to continue his literary activities and to devote more time to his hobbies of stamp collecting, fishing and woodworking when he retires to his new home on the Indian River in Florida.

LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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HEAVY DUTY GEARS

THE use of gears for power transmission dates back several hundred years. Until the age of iron and steel, gears consisted of circular wooden wheels with wooden pegs fastened to the rims to serve as teeth. The power used in operating these mechanisms was provided either by man, animal, water or wind. Wear was not too much of a problem with the crude wood-tooth gears, but later when cast iron gears came into usage some form of lubrication became necessary; lubrication also reduced some of the noise.

In those early days it was known that a greasy material would reduce noise. Animal fats were about the only lubricants available so they were used. They served the purpose satisfactorily because speeds and loads were low and mechanical wear on the teeth was not too serious. Broken teeth could be renewed without too much trouble.

By the time the steam engine was invented, however, gears were made of iron which would withstand greater loads and speeds. Later, as the machine age continued to develop, gears of greater precision were required. At first spur and straight bevel gears were satisfactory but with the advent of the steam turbine and electric motor gear design became more of a science and the herringbone type was perfected. Then the art of gear cutting really became an art because precision and strength of metal had to be coordinated.

Other types of tooth design which accompanied the development of automotive transportation and built-in power transmission units involved the helical, spiral bevel and worm. They paved the way for the hypoid gear which is virtually standard in automotive equipment today. The objectives of the designers were smooth running, quiet meshing and uniform hardness of the gear teeth to withstand wear. These objectives only can be assured, however, with effective lubrication.

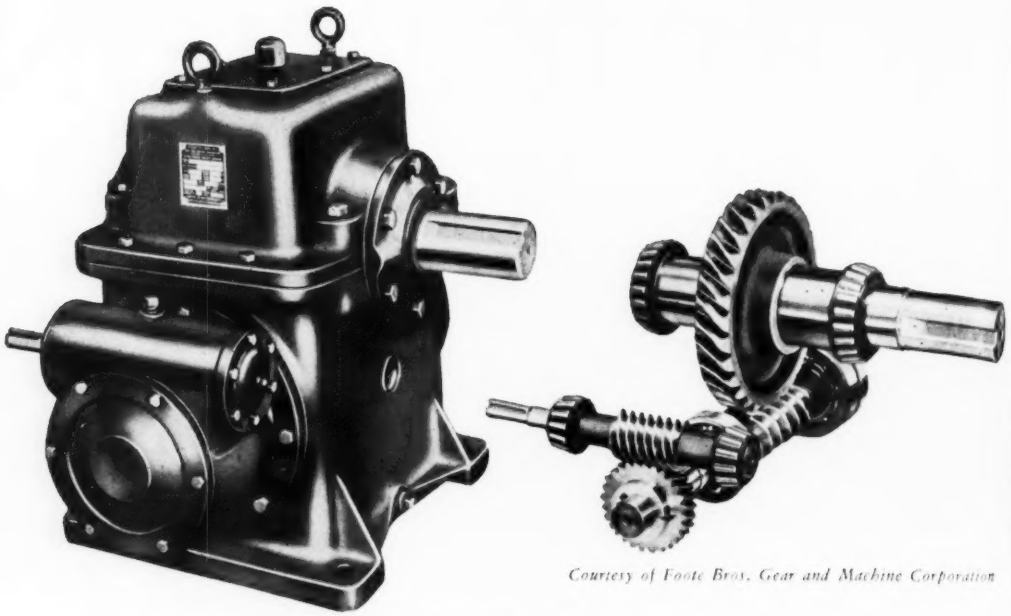
Modern industry today demands greater power and speed than ever before to satisfy the increasing demand for more and more production. At the same time the turbines and engines that produce this power require gears that have greater toughness and higher precision than ever before. Only then can power be transmitted dependably into useful channels.

This question of gear tooth structure is all the more important due to the common practice of deliberately overloading gears two or three times beyond their rated capacity, in order to increase production. This demand for ever increasing production has placed a heavier load on the gears than perhaps on any other type of mechanism.

Obviously, overloading in this matter will shorten the life of the gears, although it can be counteracted to a certain extent, but not completely, by the use of heavy duty type lubricants. The increased cost of gear replacements is felt by many, to be justified by increase in volume of goods produced.

LUBRICATION OF GEARS

The first petroleum type gear lubricants consisted of the heavy, sticky residual products which



Courtesy of Foote Bros. Gear and Machine Corporation

Figure 1 — Hy-grade Worm Gear Unit.

remained after the lighter fractions* had been removed by distillation. Residual lubricants still are widely used on spur gears employed on slow speed machines in steel, cement and rubber mills where speeds are under 100 R.P.M.

Less viscous straight mineral oils of turbine grade are better suited for high speed single helical and herringbone reduction gears where pinion speeds may be as high as several thousand R.P.M. These oils usually are highly resistant to deterioration in the presence of heat which may develop during operation.

TYPES OF LUBRICATION

"Thick film" lubrication exists where conditions of speed, load and oil viscosity are such that a heavy film of oil remains on the teeth at all times. This film separates the tooth contact areas completely. The oil supports the load entirely by hydraulic action and the important characteristic is viscosity.

"Boundary lubrication" prevails where operating conditions are such that the oil film is too thin to separate the teeth completely. High spots rub against each other and thick film lubrication cannot be maintained dependably. Under conditions of boundary lubrication gear lubricants containing "polar" or "oiliness materials" usually are effective. These additive materials are preferentially attracted to metal surfaces with a powerful bond. If operating conditions are not too severe this type of extrem pressure lubricant will function satisfactorily. How ever, if conditions get worse and tearing of meta surfaces takes place, excessive wear and eventua failure will result.

Under conditions of heavy load which may pro mote boundary lubrication the use of extreme pres sure type lubricants is advisable. The EP additive usually contain chlorine, phosphorous or sulfu compounds or combinations of these elements When the local high spots approach high tempera ture due to friction, chemical compounds of thes materials with iron are formed. These compound are softer than the iron and provide lubrication This prevents further tearing and allows the gear to operate without imminent failure.

If, however, pressures or shock loads are ex tremely high there is a point at which even EP agents can no longer be effective and excessive wear and pitting are apt to take place. Where gears are continually operated at overload conditions the use of EP lubricants will merely postpone the evil day when failure will take place.

IMPROVEMENTS IN PERFORMANCE

There are two methods being used today to im prove the life of gears:

1. Gear manufacturers are providing tougher steels and better precision construction.
2. Lubricant manufacturers are continually improving quality of gear lubricants and searching for EP agents that will give improved protection against scuffing and wear.

*Fractions: — In the petroleum industry fractional distillation results in removal of gasoline, gas oil, kerosine and lubricating oil stocks.

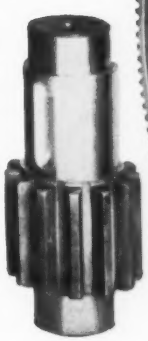
Edging Mill
Bevel Gear

Railroad Diesel
Locomotive Gear
and Pinion.

Rack and
Eccentric pinion
for flying shear.

First Intermediate
Swing Motor Gear
and Pinion for Shovel.

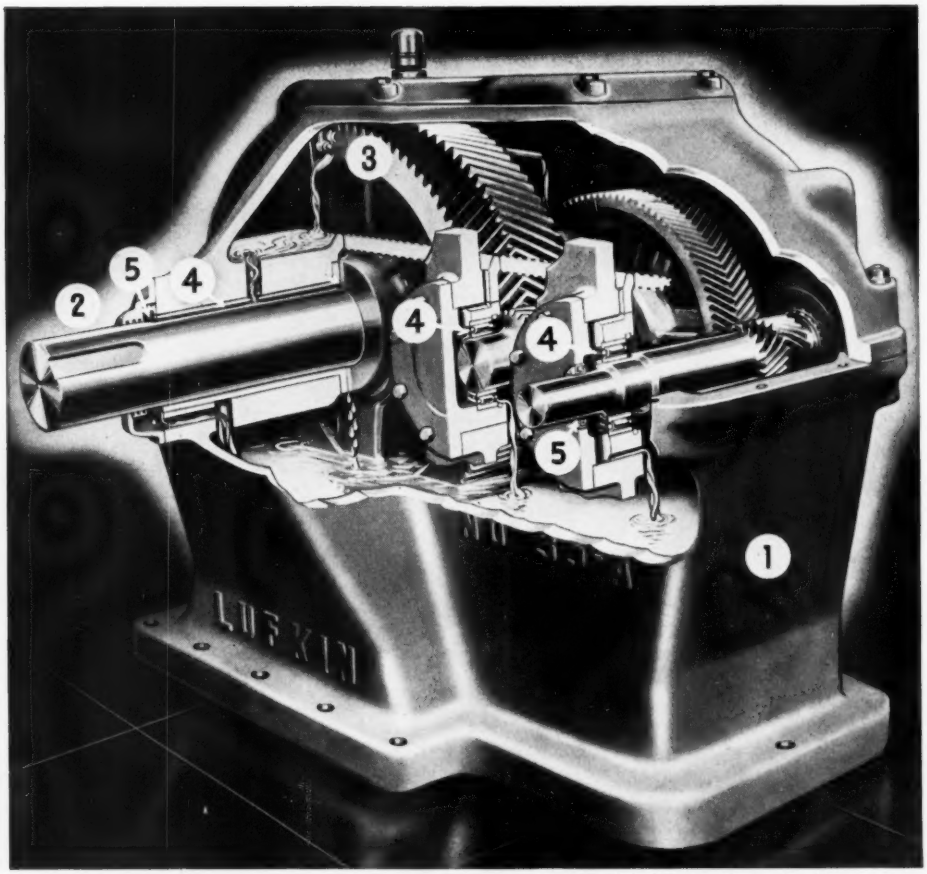
Second Intermediate Swing Motor
Gear and Shaft Pinion for Shovel.



Herringbone Gear and Pinion
for Ball Mill Drive.

Courtesy of The Tool Steel Gear and Pinion Company

Figure 2



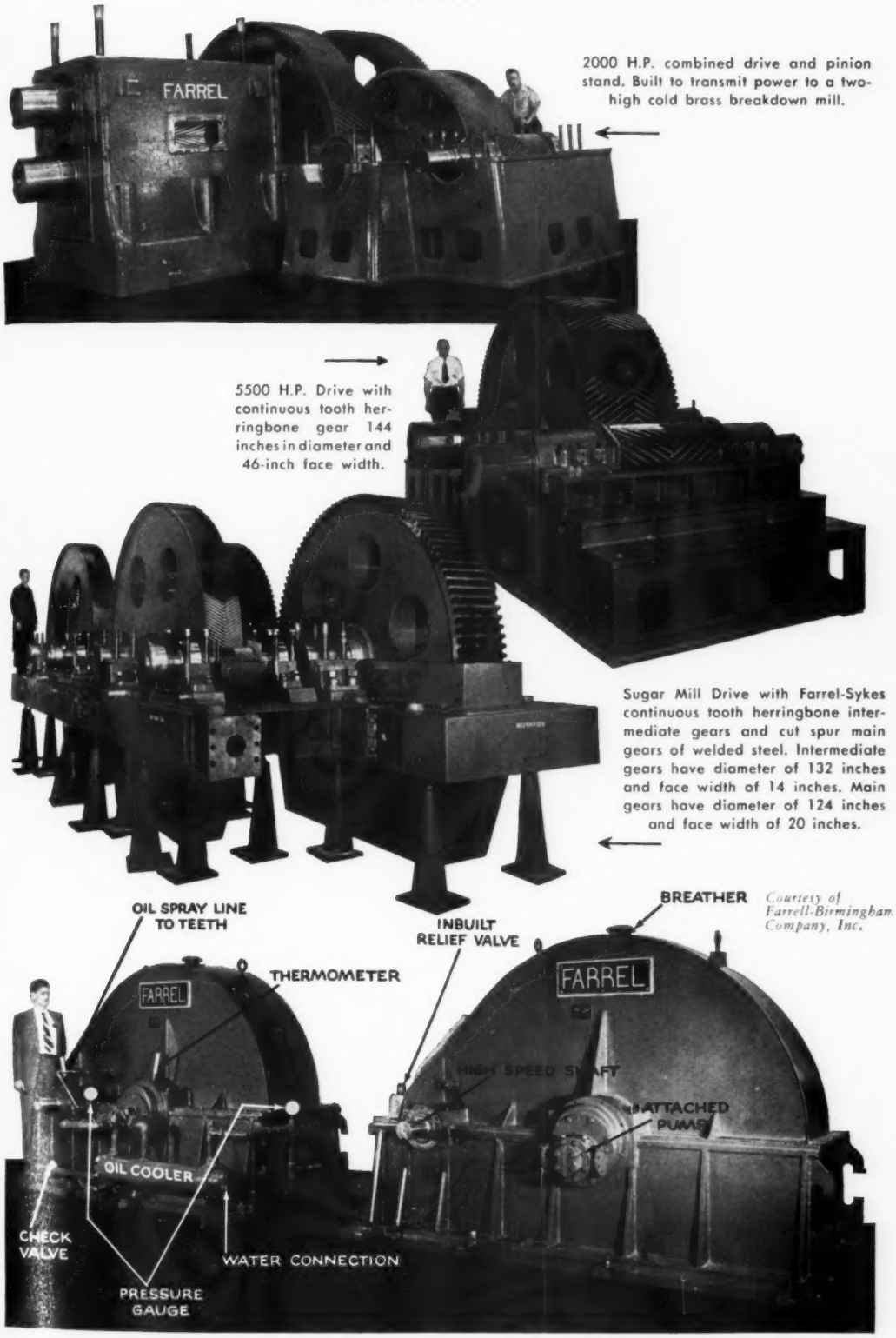
Courtesy of Lufkin Foundry & Machine Company

Figure 3 — The Lufkin gear box lubrication system. 1 — indicates the reducer housing; 2 — the forged alloy steel shaft; 3 — the precision cut herringbone gears; 4 — the bronzoid crankshaft bearing, and Hyatt Hy-load roller bearings on the pinion shafts; 5 — the patented oil seals. The main crankshaft is equipped with collar oil slingers and annular grooved drain covers.

Gear Manufacturers Activities

Since the general trend in industry is towards greater loads, higher speeds and force feed lubrication, the gear manufacturer is continually cooperating to improve gear performance. Following are some of the procedures:

1. Improved steels and heat treatments are being used. These are restricted to some extent by limitations of machinability.
2. Accuracy of manufacture is stressed. *Accurate tooth spacing* is especially important with high speed gears. Inaccuracies will result in lubricant failure as well as gear tooth failure to result in loss of power transmitted. *Tooth surface finish* also is important. Rough finishes usually result in high operating temperatures which are apt to cause deterioration of gear teeth as well as lubricant.
3. Special attention also is being given to mounting of gears to prevent damage to teeth and to make sure there is no misalignment.
4. Improved guards are being provided to keep oil in the housings and to prevent contamination.
5. The use of welded steel gears to replace cast gears is being extended. This provides gear teeth with greater strength and resistance to wear and reduces the possibility of hidden defects within the gears.
6. Manufacturers are continually modernizing and redesigning units and at the same time incorporating the latest methods of heat treatment and other metallurgical and manufacturing improvements. By taking advantage of newest techniques gear units can be made to closer tolerances and this provides increased capacity ratings compared to older styles.


FARREL
2000 H.P. combined drive and pinion stand. Built to transmit power to a two-high cold brass breakdown mill.
5500 H.P. Drive with continuous tooth herringbone gear 144 inches in diameter and 46-inch face width.
Sugar Mill Drive with Farrel-Sykes continuous tooth herringbone intermediate gears and cut spur main gears of welded steel. Intermediate gears have diameter of 132 inches and face width of 14 inches. Main gears have diameter of 124 inches and face width of 20 inches.
OIL SPRAY LINE TO TEETH
THERMOMETER
INBUILT RELIEF VALVE
BREATHER
Courtesy of Farrell-Birmingham Company, Inc.
FARREL
FARREL
HIGH SPEED SHAFT
ATTACHED PUMP
OIL COOLER
CHECK VALVE
WATER CONNECTION
PRESSURE GAUGE

Two Farrel Speed Increasers equipped with continuous tooth herringbone gears designed for oil pipeline pumping service. In operation these units increase engine speed of 327 R.P.M. to centrifugal pump speed of 2775 R.P.M.

Figure 4

Lubricant Improvements

As a result of intensive research study pertaining to gear lubricants, a number of interesting facts have been developed.

1. Seven types of additives have been found to be very effective in providing long life and satisfactory lubrication of gears, i.e.,
   (a) Fatty or Polar Compounds — Used to reduce friction.
   (b) Pour Depressants — To reduce the pour point or channel point of the lubricant so that it will flow freely at reduced temperatures.
   (c) Viscosity Index Improvers — To improve the viscosity-temperature relationship of the lubricant and minimize the viscosity spread over service temperature range.
   (d) Foam Depressants — To prevent foam or to accelerate foam collapse and thus minimize loss of lubricant due to foaming in service.
   (e) Oxidation Inhibitors — To prevent undue thickening due to oxidation and give longer life to the lubricant.
   (f) Corrosion Inhibitors — To minimize attack of water or other corrosive material on metal surfaces.
   (g) Extreme Pressure Agents —

Sulfur, Chlorine, Lead Soap	These prevent welding of metal surfaces by forming an easily sheared film of iron sulfide, iron chloride or lead sulfide.
Phosphorus	To prevent welding of meta surfaces by forming a lo melting point phosphoric allo

2. Hypoid Gear Lubricants (active EP type) car 10 to 20 times the load formerly carried whe straight mineral lubricants were used.
3. Four general types of lubricants are required fo various types of gears.

(a) Straight mineral oils	For gears operating unde conditions of compara tively low loads and ave age speeds.
(b) Straight mineral residual type oils with no additive	For general lubrication o all type gears (except hy poid) under normal ope ating conditions.
(c) Oils containing Polar or fatty materials	For bronze on steel wor gears or any others (e cept hypoid) where th film lubrication conditio may prevail.
(d) Oils containing chemically active EP additives such as sulfur, chlorine, phosphorus or lead compounds	For all gears (includin hypoid) operating unde conditions of high spe and low torque, low spe and high torque, sho loading and under hig pressures and speeds.

4. Gear teeth have two zones of lubrication.
   (a) Boundary or thin film at the location o heaviest load.
   (b) Hydro-dynamic or thick film at locations o lighter load where a comparatively hea layer of oil carries the load.
5. Although a great deal of research has been ca ried out, a formula for computing the prop viscosity and type of gear lubricant has nev been developed due to the complexity of facto

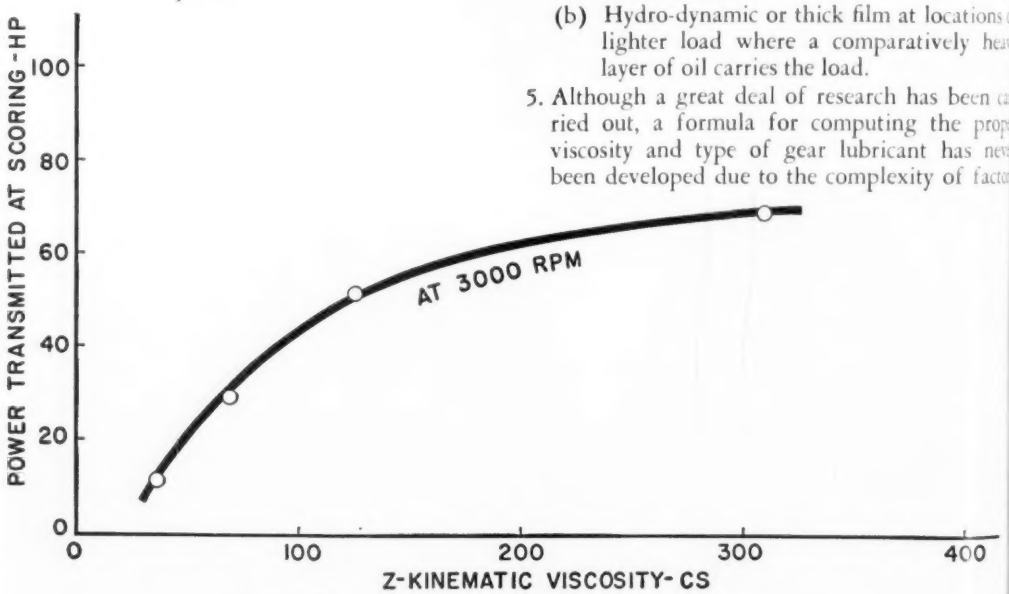


Fig. 5 — Chart showing effect of viscosity on transmitted power.

Reference: Borsoff, Accinelli and Cattaneo, "ASME" Transactions, 1951."

involved. Usual practice is to select the lubricant on basis of previous practical field experience with gear operation under various conditions. One investigator[1] has presented the following formula which it is claimed will aid in predicting loads at which scoring will take place, using speed of the pinion, viscosity of lubricant and bulk oil temperature values

$W = (aZ^{1/2} - bT) / N^{2/3}$ where
W = Scoring load
N = Rotational Speed of Pinion
Z = Nominal viscosity
T = Bulk oil temperature
a and b = Constants for the machine

This investigator further states, "Though the practical problem of selecting the right lubricant for a specific application can usually be solved by reference to the immense body of practical experience that has been accumulated in this field, the final choice is essentially an empirical one and the theoretical justification for it is not always clear. However, the progress achieved in recent years encourages the belief that a full solution of the important problem of predicting the performance of gears of all kinds is not indefinitely remote."

6. Other investigators[2] have shown that the viscosity of a gear lubricant is an important factor in the power transmitting capacity of gears. They have presented the following formula (which is an adaptation of Lewis' original equation for predicting maximum gear tooth loads).

$$W = Spby\left(\frac{ZK}{2K + ZV}\right), \text{ where}$$

W = Tooth load – pounds
S = Safe static stress – PSI
p = Circular pitch – inches
b = Width of face – inches
y = Tooth form factor
Z = Absolute viscosity in lb/min. ft.
K = Constant assumed by manufacturer
V = Pitch line velocity – fpm

Based on this modified Lewis formula, Figure 5 shows the effect of viscosity on transmitted power for gears on a test apparatus at one speed – 3000 R.P.M.

Other Investigations

(a) Research is being carried on to determine the fundamental reactions that take place when various EP agents are used.

(b) New types of EP additives are being investigated.

(c) Since it is difficult to predict types of lubricants required for various types of gears it is usually necessary to actually run laboratory tests using the specific gears involved. The following types are being used in this testing program –

Traction Motor Gears
Open Gears
High Speed Aircraft Gears
Hypoid Gears

(d) Considerable work has been done with the Buckingham[3] machine with the hope that it would differentiate between various oils and additives in regard to their prevention of scuffing. To date it has been found that scuffing starts at the same load with straight mineral as with EP lubricants. The EP agent, however, restricts tooth wear to initial scuffing, but with a straight mineral oil alone failure occurs at an accelerated rate.

GEAR FAILURES

When gears fail there are several factors which may be involved, such as:

(a) Excessive or shock loading.
(b) High speeds.
(c) Misalignment.
(d) Change in metal structure.
(e) Insufficient hardness of gear metals.
(f) Use of wrong type of lubricant.

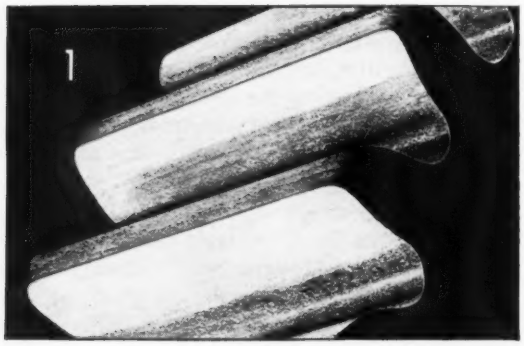
The use of the proper lubricant for the type of operation is very important. On exposed gears under relatively clean conditions the lubricant must be adhesive as well as viscous, otherwise the film cannot resist the action of centrifugal force. There is no replenishment of lubricant by drip or spray as is possible with enclosed gears. Where an excess of dust or dirt prevails the viscosity of the lubricant used on exposed gears should be reduced to enable some washing effect. This will prevent accumulation of dirt-contaminated lubricant at the base of the teeth, a condition which might lead to tooth breakage.

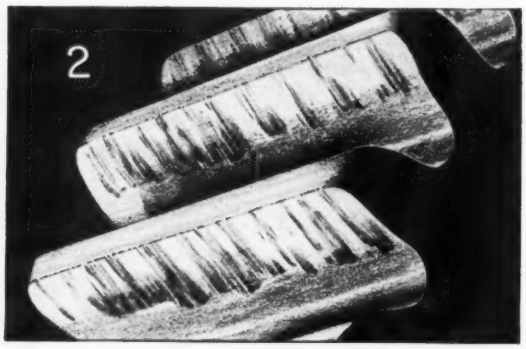
For lubrication of gears that dip into a bath it is important to choose a lubricant that at the operating temperature will be heavy enough to train with the teeth. If the oil is too light it may not carry over to give sufficient lubrication and cooling effect to the companion gear.

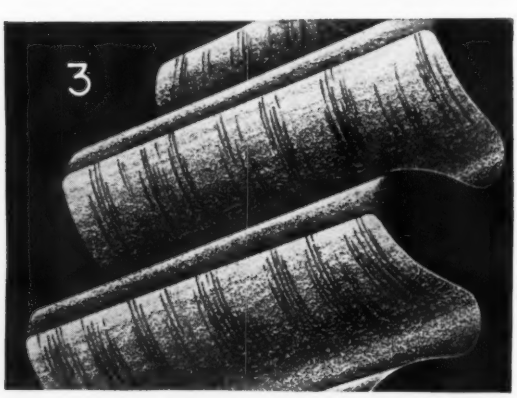
The proper lubricants will, of course, minimize wear on gears operating under moderately severe conditions but under excessively high loads, speeds, temperatures or shock conditions, even the best lubricants cannot always give full protection.

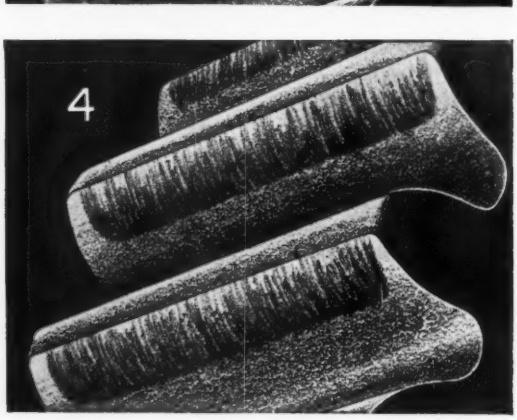
[1] E. T. Hatt in "Lubrication Engineering," August, 1952.
[2] Borsoff, Accinelli and Cattaneo, "ASME Transactions, 1951."

[3] A laboratory testing unit devised by Professor Earl Buckingham of Massachusetts Institute of Technology to determine fatigue endurance of metals. Later it was adapted to test gear lubricants.









Types of Gear Failures According to American Gear Manufacturers Assn.

Field experience with gears has shown that several types of failures are apt to occur. These have been grouped into the following classifications which will assist operators in determining causes and finding solutions for failures:

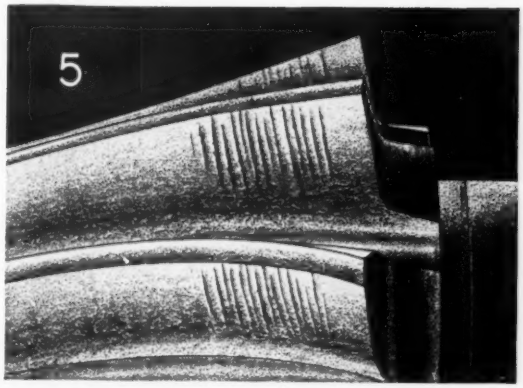
WEAR is a general term to cover sliding of metal against metal, or abrasion by lapping or scratching.

TYPE 1 — *Normal Wear* is the loss of metal from the surface of a gear tooth resulting from unavoidable abrasion, at such a rate, and to such a degree as does not prevent the gear from performing satisfactorily during its expected life.

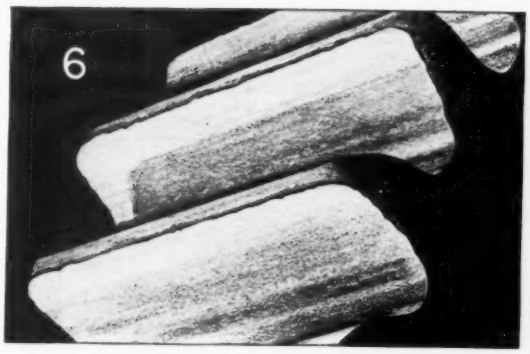
TYPE 2 — *Abrasive Wear* is surface injury caused by fine or fairly fine particles carried in the lubricant or embedded in the tooth surfaces. The particles may be metal detached from the gear teeth or bearings, abrasives not completely removed before assembling, sand or scale from castings, or other impurities in the oil or surrounding atmosphere.

TYPE 3 — *Scratching* is a form of wear characterized by deep scratches in the direction of surface sliding, caused by particles that are larger in size than those associated with abrasive wear.

TYPE 4 — *Overload Wear* is a form of wear that is experienced under conditions of heavy load and low speed in both hardened and unhardened gears. Metal seems to be removed progressively in thin layers or flakes, leaving surfaces that appear somewhat as if etched.

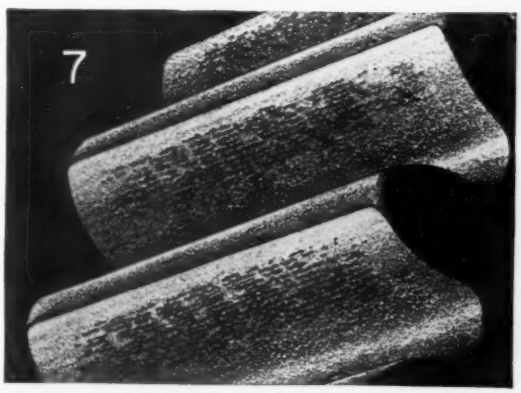


TYPE 5 — *Ridging* is a particular form of scratching that may occur on case-hardened surfaces of hypoid pinions under heavy load, and showing closely spaced grooves and ridges in the direction of surface sliding.

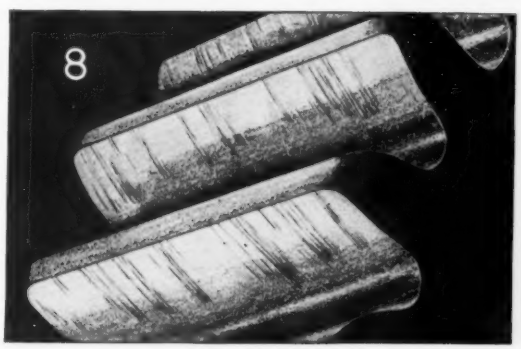


PLASTIC YIELDING is a deformation of tooth surfaces resulting from heavy loads, characterized by fins on the tip edges or ends of the teeth (not to be confused with shaving fins), and an occasional ridge and matching groove on the mate at the pitch lines. It is usually associated with ductile materials, but actually occurs with hardened steel as well.

TYPE 6 — *Rolling* is a form of plastic yielding resulting from heavy, even loads and sliding. *Peening* is a form of plastic yielding caused by localized impacts or by uneven heavy or shock loads.



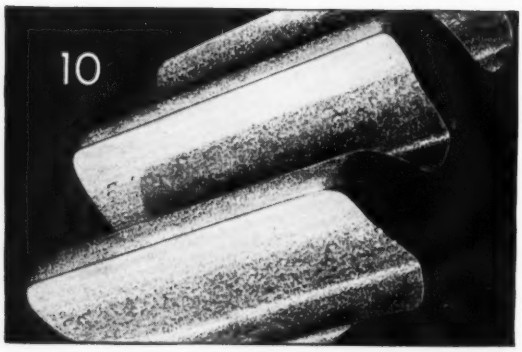
TYPE 7 — *Rippling* is a form of plastic yielding over areas of case-hardened steel surfaces under heavy sliding load, characterized by a fish-scale pattern.



WELDING is a general kind of surface deterioration occurring when pressure, sliding and rise of temperature combine to cause the lubricating film to be forced out, allowing metallic surfaces to rub directly against each other to the extent that molecular adhesion, or welding, occurs, followed by immediate tearing apart. Welding can frequently be avoided or arrested by the use of a suitable extreme pressure lubricant.

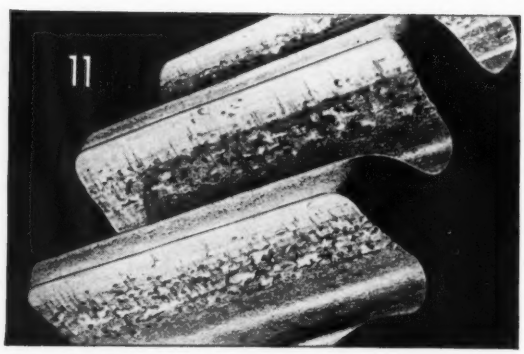
TYPE 8 — *Slight Scoring* is a minor impairment of the surface of a welding nature, showing slight tears and scratches in the direction of sliding, and starting at an area having a high combination of surface stress and sliding velocity generally occurring at or near the tip of the tooth. (The term *scoring* has been selected in this nomenclature, in preference to scuffing, seizing, galling, roping, etc.)

TYPE 9 — *Severe Scoring* is a more advanced degre of welding, showing deep scratches and adhe sions, and leading to rapid deterioration.



SURFACE FATIGUE is the formation of cavitie in the surfaces of the teeth, usually quite small a first and at separated areas of high compressiv stress often due to surface irregularities.

TYPE 10 — *Initial Pitting* may occur when a pa of gears is first started in service, and may co tinue only to the stage when local high spots hav been reduced, so that there is sufficient area o contact to carry the load without further impai ment. This type of pitting, according to exper ence, is not necessarily serious, being correctiv and nonprogressive.

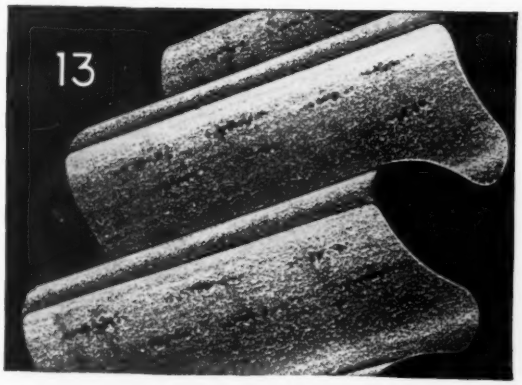


TYPE 11 — *Destructive Pitting* is the type that con tinues to progress after the initial period o operation, often at an increasing rate, to th degree that remaining unpitted areas are insuff cient to carry the load, and rapid destructio may occur by continued operation.

TYPE 12 — *Spalling* is a more extensive type o surface fatigue in which a considerable area o surface is progressively undermined and even tually breaks out in small or large flakes. It seem to occur only in case-hardened gears. Spallin may start at a crack in a way similar to pitting and does not necessarily follow the junctio between case and core.

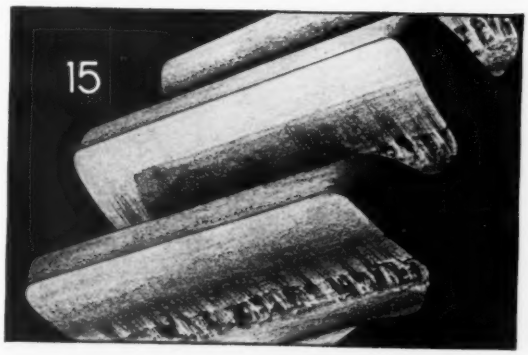
MISCELLANEOUS FORMS OF SURFACE DETERIORATION

TYPE 13 — *Corrosive Wear* is the result of chemical action on metal tooth surfaces by improper kinds of lubricants, by either acid or alkaline contamination, or by oxidization, the effect of which may be accelerated by excessive moisture in gear cases.

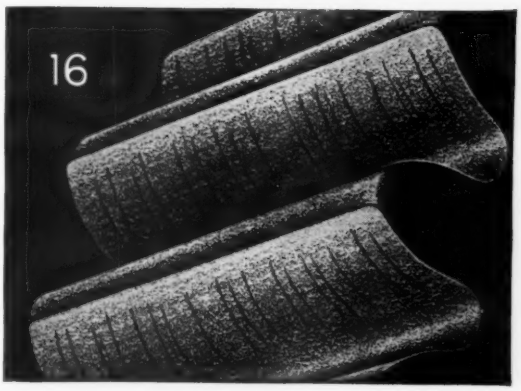


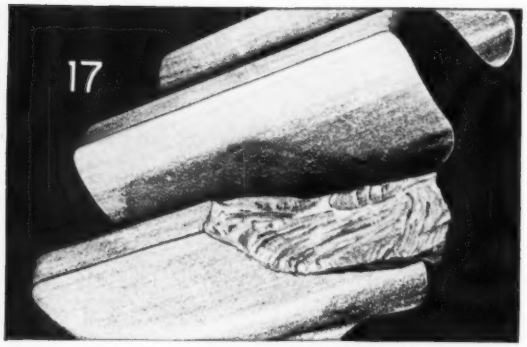
TYPE 14 — *Burning* is a discoloration and loss of hardness resulting from high temperature produced by excessive friction, caused by overload, overspeed, lack of backlash, or faulty lubrication.

TYPE 15 — *Interference* is a type of failure due to extremely heavy tooth contact on a limited area, caused by improper tooth action, such as excessive heavy contact between the tip edge of one tooth and the fillet surface of a mating tooth, and which may cause localized abrasion or gouging. Such a condition may be the result of improper design or manufacture, or assembling the gears at too close a center distance for the profile shapes existing on the teeth, or deflection.



TYPE 16 — *Grinding Checks* are fine cracks usually in a definite pattern, caused by improper grinding technique, or improper heat treatment, or both. They are usually not visible until the gears are placed in service.

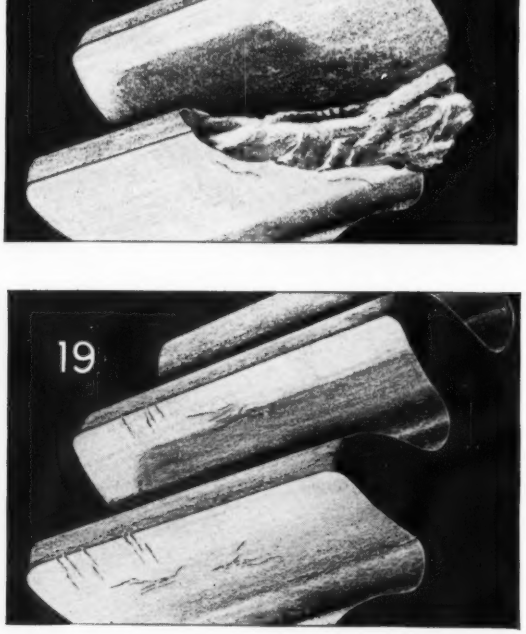




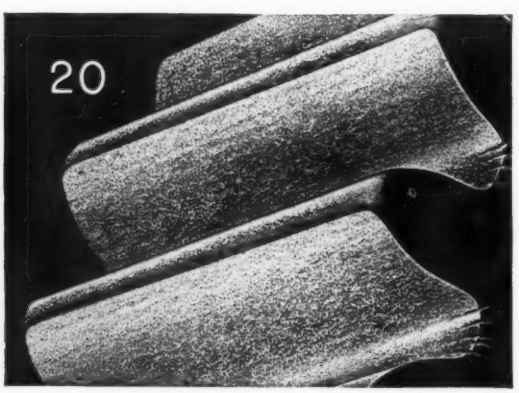
TOOTH BREAKAGE

TYPE 17 — *Overload Breakage* refers to gear tooth breakage as the direct result of an unexpected shock overload, such as may be caused by jamming of other connected machinery, and of a nature not attributable to improper design, application, or faulty manufacture of the gears.

TYPE 18 — *Fatigue Breakage* results from a large number of repetitions of a load (revolutions or cycles), rather than being caused by a single application of a shock load. A fatigue break is of a progressive nature, starting as a short crack which continues to extend until a portion, or the whole tooth, breaks loose. Discoloration and rubbing apparent on the fractured surfaces, if discernible, are indications of fatigue breakage. Sometimes fatigue fractures are characterized by a series of "contour" lines roughly concentric and spreading from a focal point. This area has a smoother appearance than the surface of the final fracture.



TYPE 19 — *Cracking* results from residual stresses induced in hardenable material by faulty manufacturing control, or from improper operating conditions. One cause is too soft a core, or some other form of improper heat treatment. Chipping and flaking represent various forms or degrees of cracking failures in which portions of teeth break out.



TYPE 20 — *Quenching Cracks* result from improper heat treatment, or from extremely sharp fillet or tool marks. They usually start at the roots or ends of the teeth. Deliberate fracturing of such a tooth will show a dark area where the crack existed.

Other Gear Failure Types

Occasionally gear failures occur which are not listed in the above types. The following is an example of such a situation:

A gear from a truck transmission showed excessive wear. The gear and a sample of the used lubricating oil were sent to the laboratory for examination. The oil was found to be in good condition and did not contribute to the failure.

A cross section was made through one of the gear teeth (see Figure 6a). The dark band around the edge of the tooth shows depth of carburization. (The mottled background around the tooth is bakelite in which the tooth was mounted.)

The depth of carburization was adequate for this application but further investigation was made. A hardness traverse was made across the carburized zone, as indicated by the white band on the photograph. The enlarged photograph of this traverse (see Figure 6b) shows individual indentations made by the hardness tester.

The hardness readings were plotted against distance from the edge of the tooth (see Figure 6c). The peak hardness was about .6mm below the surface. This is normal for a carburized surface, however, in this case the outer skin was much softer than usual; in fact it was softer than the core metal.

The outer skin apparently had insufficient carbon and it is suspected that it had been inadvertently decarburized during heat treatment (possibly caused by too much oxygen in the furnace). It is also possible that hardness of the surface changed during service. Whatever the cause the soft outer skin with its low strength could not carry the required load and excessive wear took place.

CHOOSING A LUBRICANT

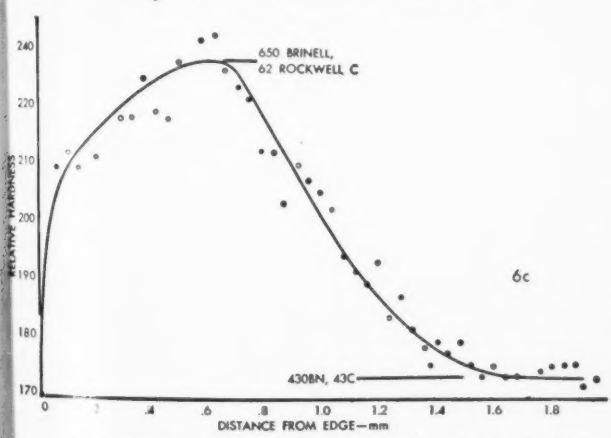
Since at the present time there is no suitable formula for arriving at the proper lubricant to use on specific gears, the choice is usually made after consultation with various groups interested in the lubrication problem.

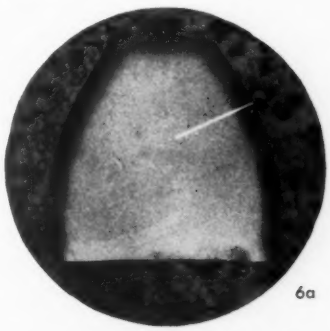
1. The gear manufacturer usually depends on previous experience with certain types of lubricants; he prefers those which he knows have performed well in similar service in the past.
2. The manufacturer of equipment in which the gears are used also is usually consulted.
3. The user of the gears, of course, can apply whatever lubricant he wishes, (after the guarantee period), but it is of utmost importance to have the right lubricant in his equipment.
4. The lubricant supplier likewise, on basis of field experience, has definite ideas as to the best lubricant to use; however, his recommendation should be tempered by the desires of the other people involved.

Other factors such as the following may also enter into the choice of a lubricant.

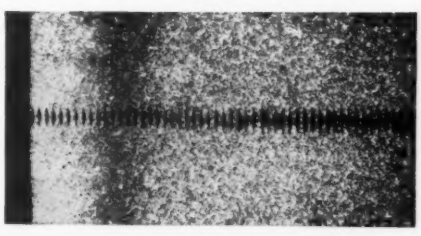
A. *Temperature*

Some gears will run at higher temperatures than others for reasons such as high ambient temperature or heavy loads. The effect of high temperature is to thin out the lubricant so it is advisable to use a heavier bodied product that will have the proper viscosity at the operating temperature. Resistance to oxidation is another requisite of the lubricant.





6b



6a — Cross section of gear tooth showing depth of carburization and location of hardness traverse.
6b — Enlarged photograph of hardness traverse showing individual indentations. 6c. — Hardness readings at various distances from the edge of the tooth.

Figure 6

B. *Speed*

Gears operating at high speed usually need a lubricant of reduced viscosity to provide adequate lubrication, cooling, and operation with minimum tooth friction. Under lower speed conditions, however, heavier lubricants are required according to the prospective operating temperatures. Friction is of less consideration when lower speeds are involved; the ability of the lubricant to follow or train with the teeth and maintain a complete film is more important.

C. *Method of Application*

This will determine to a great extent the type of lubricant.

D. *Load*

The load or pressure to which gear teeth may be subjected must be considered when deciding upon the viscosity or body of the lubricant. Heavily loaded gears require higher viscosity, more adhesive type lubricants. Such products provide a cushioning effect to offset the effect of tooth impact.

E. *Contamination*

The entrance of water or other contaminants into the lubricant makes it necessary to use lubricants that can be separated easily from the contaminating materials.

METHODS OF APPLICATION

Ideally speaking, gears should have oil-tight housings that will keep out contaminants and keep in the lubricant. This, however, is not always possible and the lubricant often must function under conditions which are far from ideal. The following methods of application are used in various gear assemblies:

1. *Circulating System*

A pump delivers lubricant by spray or flood to a location near or directly at the point of tooth mesh. Some operators claim that lower operating temperatures are obtained if application is made after the point of mesh. The pump operates with a separate motor or is sometimes directly connected with the gears being lubricated. This method is suitable to all normal operating speeds. A comparatively low viscosity product usually is used and an oil-tight housing is required.

2. *Bath System*

Enough lubricant is applied to flood several teeth on one gear. The lubricant must adhere to the teeth and carry over to the other gear or gears in the unit. It should be adhesive but not channeling. Gears with pitch-line velocity up to 2000 ft. per minute can utilize this method. An oil-tight housing is also required for this method.

3. *Idler Immersion*

This is similar to the bath system but lubri- cant is picked up from the sump by an idle and delivered to the gear teeth.

4. *Slush Pan Lubrication*

Here slush pan or sump is located below the lowest gear. The lubricant level is kept at a height sufficient to submerge a few teeth. Lubricant is carried to the point of mesh and delivered to other gears. The oil should be semi-fluid and sufficiently tacky to adhere well to the teeth. This method is suitable for use with semi-enclosed gears.

5. *Intermittent Lubrication*

In this method heavy viscous lubricants are applied by paddle, dripping or pouring. It is sometimes necessary to heat before application. Heavy lubricants are sometimes cut back with solvents to provide easy application by brush or spray. The intermittent method is suitable for heavily loaded gears running at low speeds and can be used when housing is absent or inadequate.

Cut back type lubricants containing solvents should be used only where there is ample ventilation. Solvents may have a toxic effect on personnel and in some cases may also present a flammability hazard.

CONCLUSION

Modern gears are being called upon to perform heavier work than ever before, due, very often, to the tendency in industry to speed up production considerably above the rated machine capacity. In many cases this is done deliberately with the knowledge that the expected life of the gears will be shortened, but offset by increase in production.

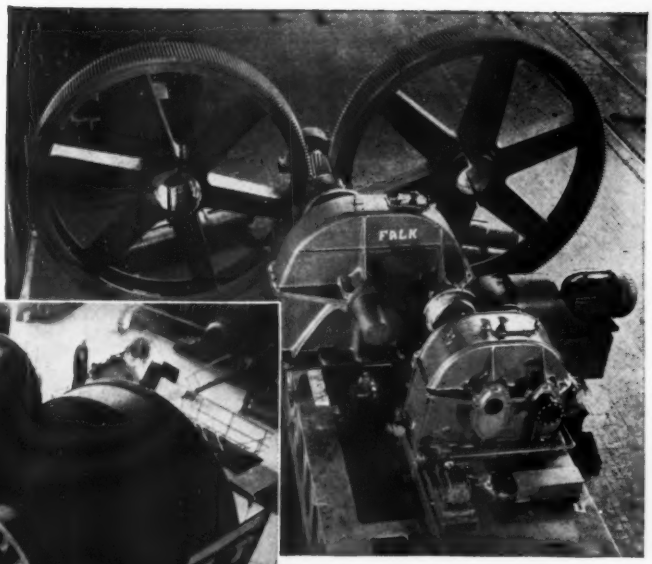
Gear manufacturers, by redesigning, modernizing and using better steels, are now producing precision gears that give better performance than ever before.

Lubricant manufacturers are continuing with extensive research to produce tougher lubricants to keep pace with increasing demands of industry.

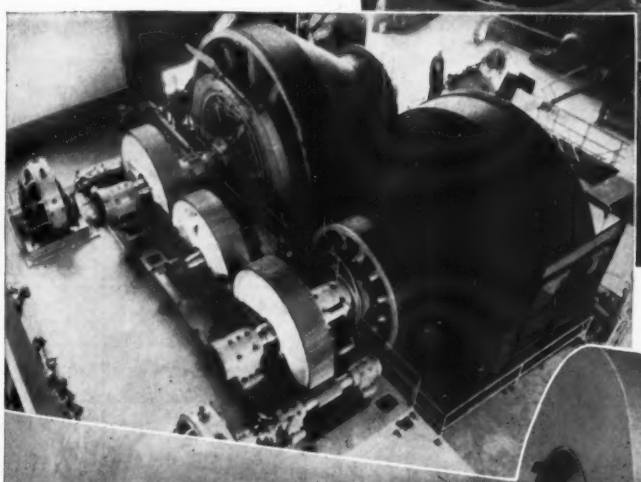
There are limits, however, to overload. Beyond these limits even the highest quality steels and the most durable extreme pressure lubricants may not be able to function dependably.

The American Gear Manufacturers Association has classified gear tooth failures as shown in the publication "AGMA Standard Nomenclature of Gear Tooth Wear and Failure," and reproduced Gear Failure Types 1 through 20 in this article. With these illustrations of what can happen if there is not perfect accord between the lubricant, the steel and the load conditions, it is hoped that better understanding of the problem of gear lubrication will result.

Gearing used for sugar mill drive which is driven by a turbine through the high speed unit in the foreground. →



← Tandem Mine Hoist Drive.



Cement Kiln Drive for dual pinion and dual set of speed reducers motors and couplings. ↓

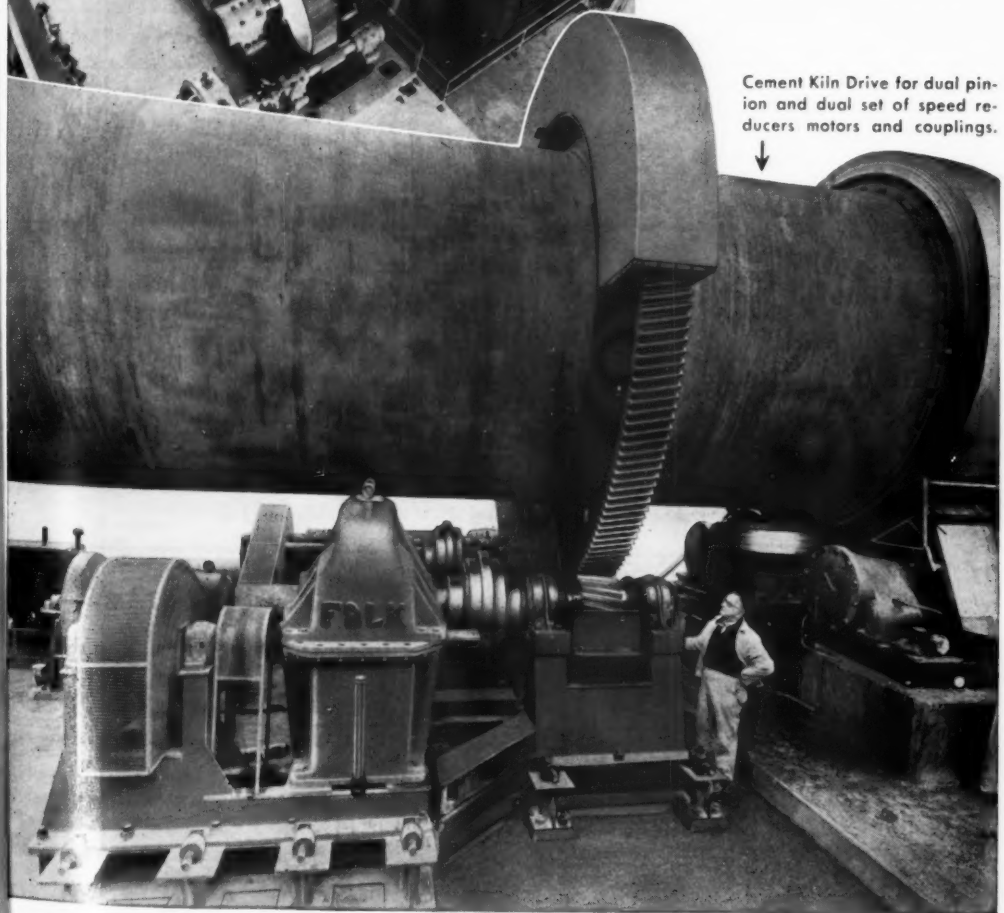


Figure 7 *Courtesy of The Falk Corporation*

TEXACO LUBRICANTS FOR INDUSTRIAL GEARS

TYPE OF GEAR	DESCRIPTION	AMBIENT TEMPERATURES	NORMAL OPERATION	HEAVY DUTY, WHERE EXTREME PRESSURE LUBRICATION REQUIRED	IN PRESENCE OF WATER OR CHEMICALS
SPUR, BEVEL SPIRAL BEVEL, ANNULAR OR INTERNAL	Gears enclosed, casings oil tight, bearings separately lubricated.	Below 40° F.	Thuban 80 Regal Oil PC R&O	Meropa Lubricant—1	
		40° to 100° F.	Thuban 90 Regal Oil G R&O	Meropa Lubricant—3	
		Above 100° F.	Thuban 140	Meropa Lubricant—6	
	Gears enclosed, casings oil tight, gear lubricant to serve bearings as well.	Below 40° F.	Regal Oil F R&O Algol Oil	Meropa Lubricant—1	
		40° to 100° F.	Regal Oil G R&O Thuban 90	Meropa Lubricant— 2 or 3	
		Above 100° F.	Regal Oil H R&O Thuban 90	Meropa Lubricant—3	
	Gears entirely exposed, hand lubricated.	Below 40° F.	Crater 1 or 2X Fluid	Meropa Lubricant— 2 or 3	Crater 1X
		40° to 100° F.	Crater 1, 2 or 2X Fluid	Meropa Lubricant— 3 or 4	Crater 1X, 2 or 2X Fluid
		Above 100° F.	Crater 3 or 5X Fluid	Meropa Lubricant—6	Crater 2-X or 2X Fluid
	Gears exposed, bath lubricated.	Below 40° F.	Regal Oil G R&O Thuban 90	Meropa Lubricant—3	
		40° to 100° F.	Thuban 140 or 250 Crater 00, 0 or 2X Fluid	Meropa Lubricant— 6 or 8	Crater 1X
		Above 100° F.	Thuban 250 Crater 0, 1, 2 or 2X Fluid	Meropa Lubricant—8	Crater 1X or 2X Fluid
HELICAL OR HERRINGBONE	Gears enclosed, casings oil tight, bearings separately lubricated.	Below 40° F.	Regal Oil G R&O Thuban 90	Meropa Lubricant—3	
		40° to 100° F.	Regal Oil G R&O Thuban 90 or 140	Meropa Lubricant— 3 or 6	
		Above 100° F.	Thuban 140	Meropa Lubricant—6	
	Gears enclosed, casings oil tight, gear lubricant to serve bearings as well.	Below 40° F.	Regal Oil PE R&O Algol	Meropa Lubricant—1	
		40° to 100° F.	Regal Oil F R&O Thuban 80	Meropa Lubricant— 1 or 2	
		Above 100° F.	Regal Oil G R&O Thuban 90	Meropa Lubricant—3	
	Gears entirely exposed, hand lubricated.	Below 40° F.	Crater 0, 1 or 2X Fluid	Meropa Lubricant—3	Crater 1X or 2X Fluid
		40° to 100° F.	Crater 1, 2 or 2X Fluid	Meropa Lubricant— 6 or 8	Crater 1X, 2 or 2X Fluid
		Above 100° F.	Crater 1, 2 or 2X Fluid	Meropa Lubricant—8	Crater 1X or 2X Fluid
	Gears exposed, bath lubricated.	Below 40° F.	Regal Oil G R&O Thuban 90	Meropa Lubricant—3	Crater 1X
		40° to 100° F.	Thuban 140 or 250 Crater 00, 0 or 2X Fluid	Meropa Lubricant— 6 or 8	
		Above 100° F.	Thuban 250 Crater 00, 0 or 2X Fluid	Meropa Lubricant—8	

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TEXACO LUBRICANTS FOR INDUSTRIAL GEARS

TYPE OF GEAR	DESCRIPTION	AMBIENT TEMPERATURES	NORMAL OPERATION	HEAVY DUTY, WHERE EXTREME PRESSURE LUBRICATION REQUIRED	IN PRESENCE OF WATER OR CHEMICALS
WORM	Gears enclosed, casings oil tight, bearings separately lubricated.	Below 40° F.	Regal Oil PC R&O Thuban 80	Meropa Lubricant—1	
		40° to 100° F.	Honor Cylinder Oil Thuban 90 Regal Oil G R&O	Meropa Lubricant—3	
		Above 100° F.	Honor Cylinder Oil or 650T Cylinder Oil Thuban 140	Meropa Lubricant—6	
	Gears enclosed, casings oil tight, gear lubricant to serve bearings as well.	Below 40° F.	Regal Oil PC R&O Thuban 80 or 90	Meropa Lubricant— 1 or 3	
		40° to 100° F.	Honor Cylinder Oil Thuban 90 Regal Oil G R&O	Meropa Lubricant—3	
		Above 100° F.	Honor Cylinder Oil or 650T Cylinder Oil Thuban 140	Meropa Lubricant—6	
	Gears entirely exposed, hand lubricated.	Below 40° F.	Regal Oil G R&O Thuban 90	Meropa Lubricant—3	
		40° to 100° F.	Thuban 140	Meropa Lubricant—6	Crater 1X or 2X Fluid
		Above 100° F.	Thuban 140 Crater 0, 1 or 2X Fluid	Meropa Lubricant—6	Crater 1X or 2X Fluid
RACK AND PINION	Gears exposed, bath lubricated.	Below 40° F.	Regal Oil G R&O Thuban 90	Meropa Lubricant—3	
		40° to 100° F.	Thuban 140	Meropa Lubricant—6	Crater 1X
		Above 100° F.	Thuban 140 or 250	Meropa Lubricant— 6 or 8	Crater 1X
	Teeth entirely exposed, hand lubricated.	Below 40° F.	Crater 00, 0, 1 or 2X Fluid	Meropa Lubricant—6	Crater 1X or 2X Fluid
		40° to 100° F.	Crater 1, 2 or 2X Fluid	Meropa Lubricant— 6 or 8	Crater 1X, 2X or 2X Fluid
		Above 100° F.	Crater 3 or 5X Fluid	Meropa Lubricant— 8 or 10	Crater 2X, 5X or 2X or 5X Fluid
	Teeth exposed, bath lubricated.	Below 40° F.	Regal Oil G R&O Thuban 90 Crater 00 or 2X Fluid	Meropa Lubricant—3	Crater 1X
		40° to 100° F.	Thuban 140 Crater 00, 0 or 2X Fluid	Meropa Lubricant—6	Crater 1X or 2X Fluid
		Above 100° F.	Thuban 140 or 250 Crater 0 or 2X Fluid	Meropa Lubricant— 6 or 8	Crater 1X or 2X Fluid

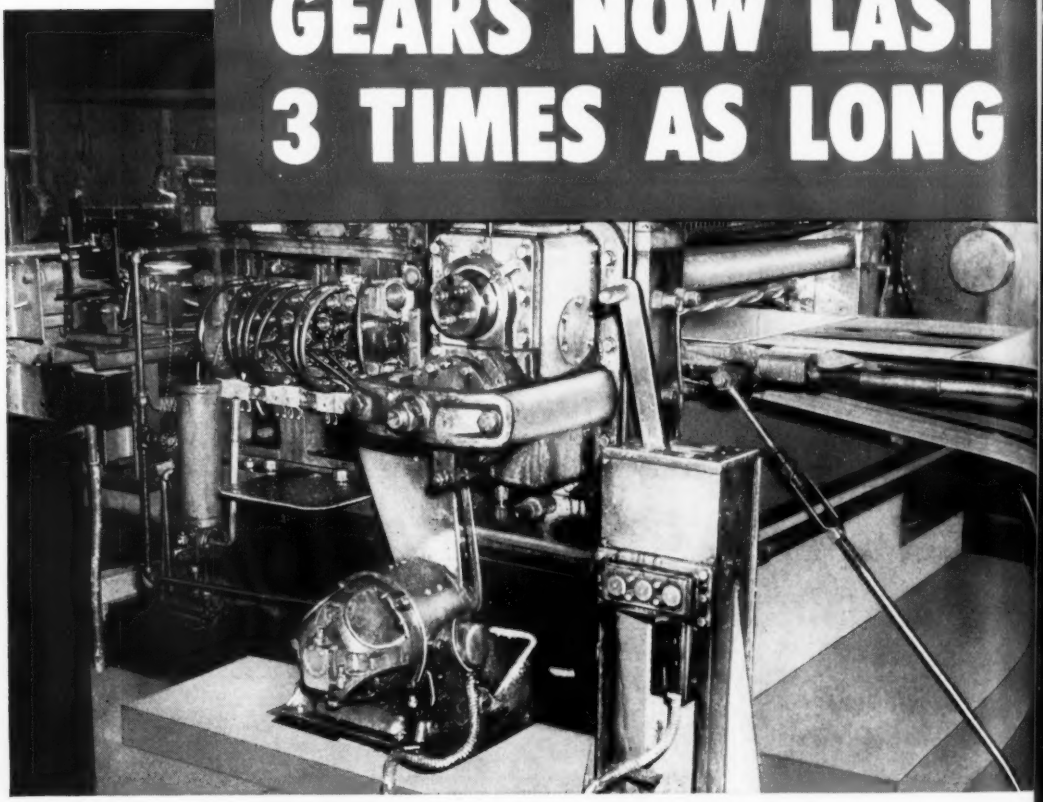
NOTES: The above recommendations naturally are more or less general, based on average pressures and for small to medium sized gears:

1. In case of light loads or high speeds: Use next lighter grade of gear lubricant.
2. If gears are very large: Use somewhat heavier grade than that recommended above.
3. Meropa Lubricants are highly resistant to water and should be recommended where both a water resistant and an EP lubricant is desired.
4. For cast gears: Use the next heavier grade of gear lubricant recommended.
5. Texaco Craters under certain conditions are recommended for enclosed gears and exposed worm gears.
6. Should ambient temperatures be extremely low or high or should any uncertainty exist as to the correct lubricant recommendation for a specific application, consult your local Texaco Lubrication Engineer.

• • •

Note: It is very important that there be adequate ventilation, due to the nature of the solvent, when Crater Fluid is applied, in order to carry away vapors and speed up the evaporation. The solvent is non-inflammable.

WEIRTON'S SHEAR GEARS NOW LAST 3 TIMES AS LONG



The Situation: Weirton Steel Company, Weirton, W. Va., was having trouble with the gears of seven Hallden tin plate shears. Gears were pitting badly and running so hot that a continuous vapor rose from the vent. Gear life was only about five months.

The Remedy: A Texaco Lubrication Engineer was called in, asked to study the problem. He recommended *Texaco Meropa Lubricant* and the lubricant on one shear drive was changed over as a test.

The Results: Improvement in performance with *Texaco Meropa Lubricant* was so marked that within six months the other six shears were also changed over. The average life of the gears is now eighteen months.

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